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Operations Overview for the ANDRILL McMurdo Ice Shelf Project, Antarctica

T. Falconer
Victoria University of Wellington, tamsin.falconer@vuw.ac.nz

A. Pyne
Victoria University of Wellington

M. Olney
Florida State University

M. Curren
Florida State University

ANDRILL-MIS Science Team

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T. Falconer[1]*, A. Pyne[1], R. Levy[2], M. Olney[3], M. Curren[3] & the ANDRILL-MIS Science Team[4]

[1]Antarctic Research Centre, Victoria University of Wellington, PO Box 600, Wellington - New Zealand
[2]ANDRILL Science Management Office, University of Nebraska-Lincoln, Lincoln, NE, 68588-0341 - USA
[3]Antarctic Research Facility, Florida State University, Tallahassee, FL, 32303 - USA
[4]http://www.andrill.org/support/references/appendixc.html

**Corresponding author* (tamsin.falconer@vuw.ac.nz)

Abstract - During the austral summer of 2006, a record-setting 1 284.87 metre (m)-long rock and sediment core (ANDRILL [AND]-1B) was recovered from beneath the McMurdo Ice Shelf (MIS) in 917 m of water. A custom built drilling system comprising a UDR-1200 rig, jack-up platform, hot water drill, sea riser, and diamond-bit wireline coring string was set up on the McMurdo Ice Shelf approximately 9 kilometres (km) from Scott Base (NZ). The drilling sytem employed technology developed to handle challenging environmental conditions including an 85 m-thick ice shelf 'platform' that moved both laterally and vertically, strong tidal currents, and high winds. Drill site set up commenced on 18 August 2006, and the first core for AND-1B was recovered on 31 October 2006. Drilling operations continued through 26 December 2006. Science operations were conducted at the drill site, in both the borehole and a purpose built laboratory (lab) complex, and at the Crary Science and Engineering Center (CSEC), McMurdo Station (USA). Drill site science operations involved downhole logging, which was carried out in the borehole casing and in parts of the open hole, fracture studies, and physical properties measurements. Core was transported from the drill site to McMurdo Station, where it was split, scanned, described, and sampled for initial characterisation. Once initial studies were completed, the core was packed into crates for shipment to the Antarctic Research Facility (ARF; core respository) at Florida State University in the United States.

DRILL SITE OVERVIEW

The ANDRILL MIS Project drilling and science operations occurred at two primary locations: the drill site and Crary Science and Engineering Laboratory, McMurdo Station. The following provides a summary of key operational events and data.

SUMMARY DRILLING DATA FOR AND-1B

Drill rig location (1 October 2006):
.................................77.8894417S, 167.0893282E
Ice-shelf thickness: .... ~82 metres (m)
Freeboard: ....18.9 m
Firn-ice transition: .... ~25 m
Ice-shelf lateral movement
(from 31 Oct 2006 to 11 Jan 2007): ......21.93 m
Maximum ice-shelf tidal range
(uncorrected GPS data): .... ~1.7 m
Depth to mean seafloor
(from platform cellar floor):................. 935.76 m
Sea riser spud-in:....................... 31 October 2006
Sea riser shoe set at:........................17.18 metres below seafloor (mbsf)
PQ casing shoe (PQ3 bit) set at:............. 238 mbsf
HQ core interval to:............................... 702 mbsf
HQ casing shoe (HQTT bit) set at:....... 690.5 mbsf
NQ cored interval to:......................1 284.87 mbsf
Coring completed:................... 26 December 2006
Sea riser cut: ....11 January 2007
Sea riser recovered: ....12 January 2007

ICE SHELF THICKNESS

The ice shelf at the MIS Project drill site was expected to be greater than 70 m thick based on the depth of an initial hot water drill hole (HWD-1) made through the ice shelf in 2003 (0.1 km west of the MIS Project drill site). In addition, a hot water drill (HWD) test carried out in February 2006 (approximately 4.1 km east of the MIS Project drill site) drilled through 97 m of ice and provided an estimate of maximum thickness. The ice shelf at the MIS Project drill site was penetrated by the HWD in late September 2006 and determined to be approximately 82 m thick. Sea level was initially measured in the ice hole at 19.7 m below the cellar floor, indicating the ice shelf had approximately 19 m of freeboard.

LATERAL MOVEMENT

The ice shelf in the area of the MIS Project drill site moves in a westerly direction at approximately 100 m/yr. From the sea riser spud-in date (31 October 2006) to the sea riser cut- off date (11 January 2007) a total lateral movement of 21.93 m at 263.8 degrees was measured (Fig. 1).

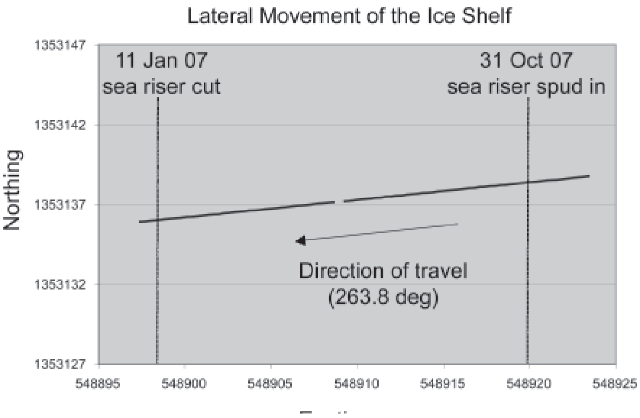


Fig. 1 – Distance and direction of total lateral movement of the MIS Project Drill Site located on the McMurdo Ice Shelf.

Modelling of stress on the sea riser took into account known ice shelf movement and maximum water-column current models which were developed by Robinson & Pyne (2003) based on current measurements made at HWD-1 in 2003. Lateral ice-shelf movement was also taken into account during drill site preparation as a compacted snow pad had to be constructed a year prior to drilling during the 2005–2006 Antarctic field season. The compacted surface was constructed in a position that would move over the selected drilling location by the start of the drilling season (nominally 1 October 2006).

Lateral movement of the drill site was monitored from 18 October 2006 to 13 January 2007 using Global Positional Satellite (GPS) equipment mounted on the roof of the drill site lab complex. GPS equipment was supplied and installed by UNAVCO.

TIDAL MOVEMENT

An estimate presented in Robinson (2006) predicted that tidal motion would cause a 1.3 m maximum vertical movement of the ice shelf in the vicinity of the drill site. This estimate was based on tidal measurements collected approximately 10 km away from the drill site. The set-up of the rig and platform and the tide compensation equipment was designed to accommodate this amount of vertical motion while maintaining constant tension on the sea riser and subsequent casings. Robinson (2006) also estimated the tidal cycle and likely water current speed and direction beneath the ice shelf, through the water column, and at the seafloor.

GPS monitoring at the drill site also recorded tidal (vertical) movement. Measured vertical movement generally followed the tidal cycle prediction presented in Robinson (2006) (Fig. 2). Note that GPS data for vertical movement presented here have not been corrected for barometric pressure changes or other vertical uncertainties.

WATER CURRENTS

Water currents were not measured at the drill site, as it was not possible to deploy current measurement instruments through the access hole in the ice shelf. The performance of the sea riser was affected by water-column currents, which caused a slow period (2-3 second) "vibration" in the riser. This vibration was more pronounced during the 1–2 days that followed reaming of the ice shelf hole with the hot-water reaming tool. It is likely that reaming the access hole allowed for increased movement of the riser and caused the riser to impact against the hard bottom edge of the ice shelf hole. This vibration (probably vortex induced vibration) was not predicted during the drill system design phase and was not included in initial stress and performance modelling for the sea riser.

WEATHER

Meteorological conditions for the region around the drill site were summarised in the ANDRILL

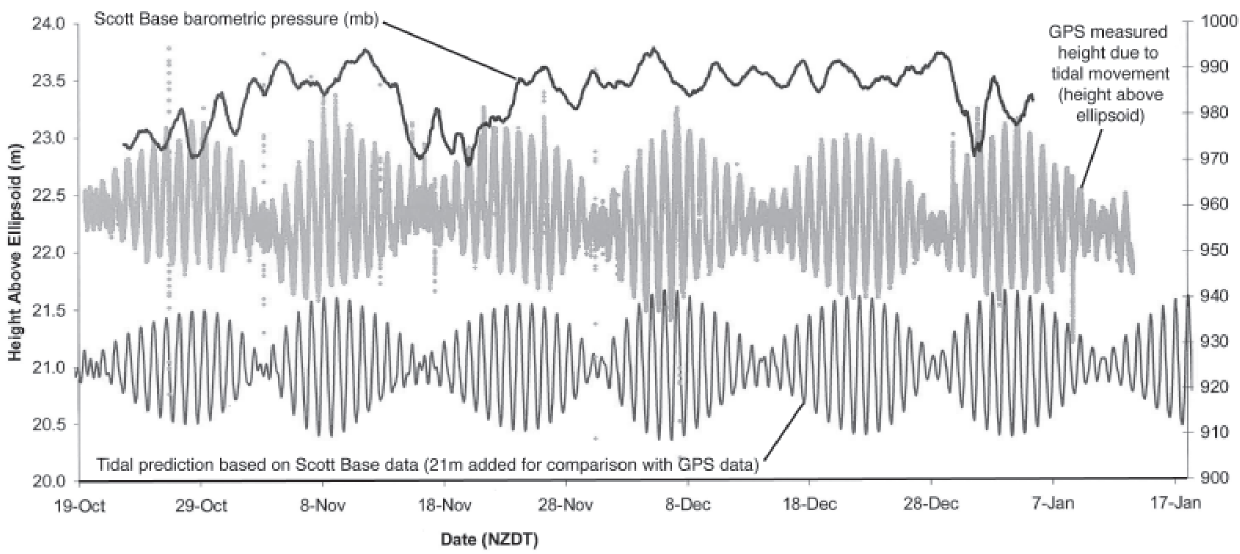


Fig. 2 – Diagram showing predicted and measured vertical movement of the McMurdo Ice Shelf (height above the ellipsoid) plotted with barometric pressure. Right-hand x-axis is barometric pressure (mb).

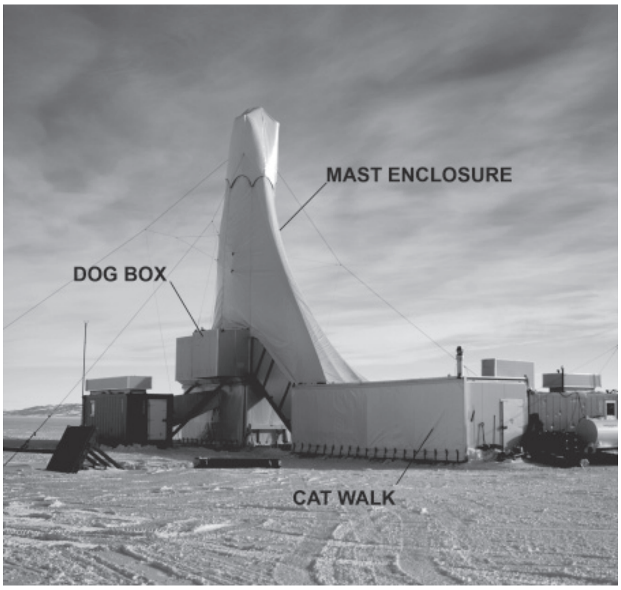


Fig. 3 – The ANDRILL drill rig and platform showing the PVC mast enclosure, the drillers' dog box, and cat walk.

Comprehensive Environmental Evaluation (Huston et al. 2006). The main meteorological concern for the drilling operation phase of the MIS Project was wind speed and its potential effect on stability of the soft shell mast enclosure (Fig. 3). A prototype of the enclosure (composed of a lighter-weight fabric than that incorporated in the final product), which was erected on the rig in Christchurch, failed in winds of approximately 48 kts (90 km/h). As a consequence of this failure, a wind-speed monitor linked to an ultrasonic wind speed measuring device, located approximately 6.5 m above the ground surface on top of the UDR power pack near the drilling platform, was incorporated into the drill rig dogbox (Fig. 4). Furthermore, the streamlined shape of the enclosure was aligned into the strongest winds, which were expected to come from the south.

On 30 October the enclosure performed successfully in wind gusts that reached 40 kts (74 km/h), after which the alarm points for wind monitoring were reset so that the high wind alert only showed when wind speed reached 40 kts (74 km/h).

DRILLING OPERATIONS

Projected and actual drilling operations schedule and timeline are presented in figures 5 and 6, respectively.

SETUP

Between 18 and 24 August 2006, the first set of ANDRILL drill site equipment was towed to the drill site using a New Zealand Antarctic Programme Caterpillar D4 from Scott Base, the ANDRILL Caterpillar D6, and two ANDRILL Hagglunds. On 13 September, three United States Antarctic Program (USAP) Caterpillar Challengers from McMurdo Station towed 26 modified shipping containers to the drill site. On 18 September, a team of four ANDRILL personnel began to set up drill site equipment. Persistent windy conditions occurred during this initial setup period, including a five-day storm that created large snowdrifts in and around the equipment. However, by the time the drill crew arrived on site in early October, all the containers and components had been positioned, connected, weatherproofed, and most of the systems had been warmed up. In addition, the well for the HWD had been created and the HWD had been set up. The drill team completed erecting the mast enclosure on 12 October, and started deploying the sea riser on 18 October.

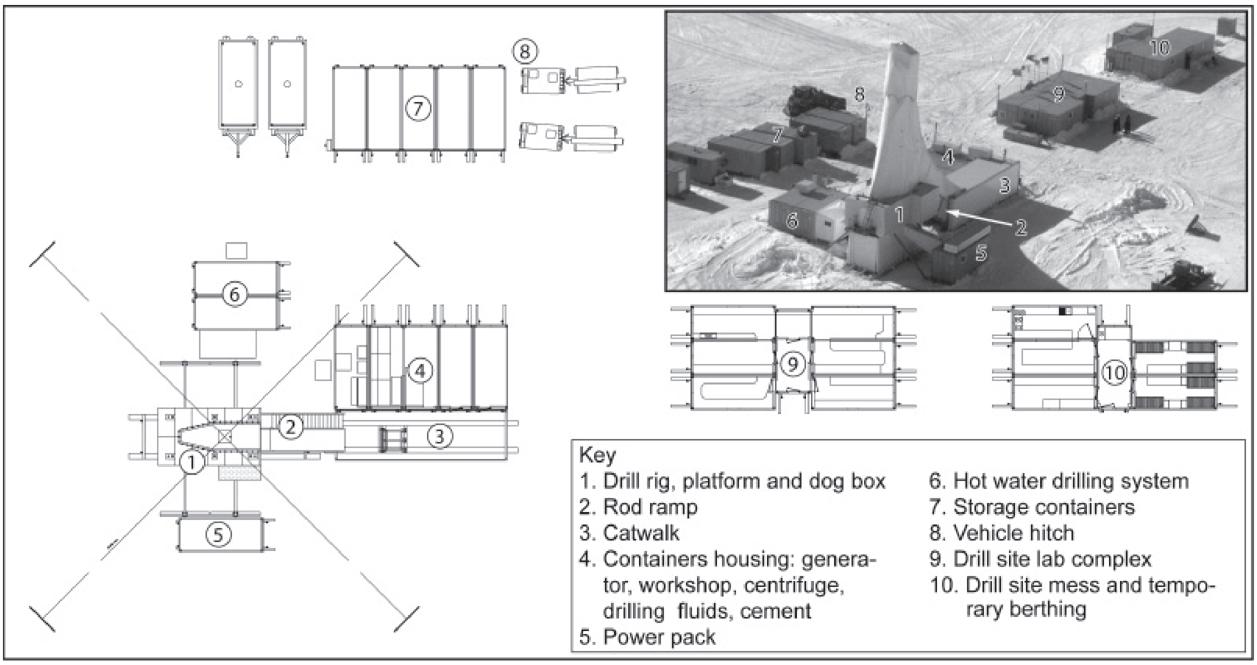
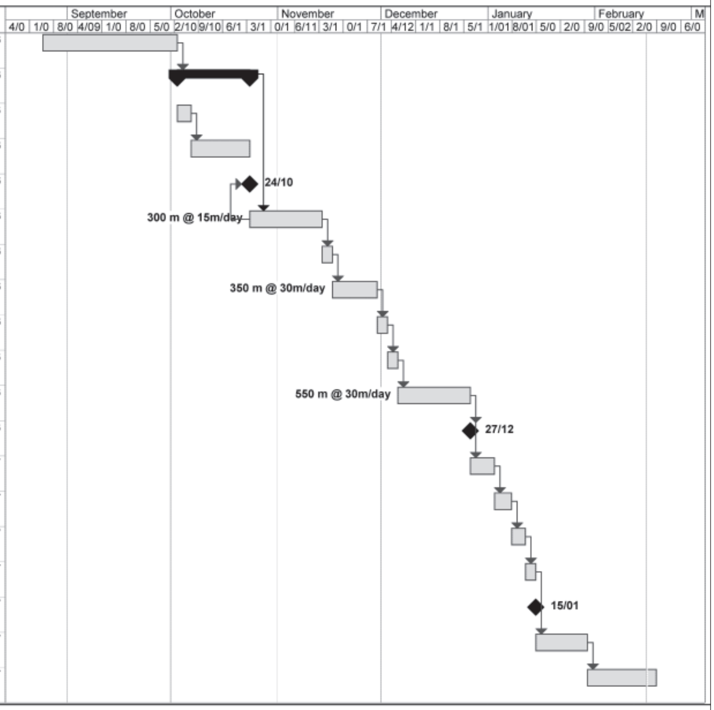


Fig. 4 – Plan of the MIS Project Drill Site layout. Inset: aerial photograph of the drill site.

MIS Drill Season Timeline v1.1 01 Aug 06

ID	Task Name	Duration	Start	Finish
1	Setup phase 1(Winfly)	39 days	Fri 25/08/06	Tue 3/10/06
2	Setup phase 2	21 days	Tue 3/10/06	Tue 24/10/06
3	SB/Orientation	4 days	Tue 3/10/06	Sat 7/10/06
4	Setup incl SR installation	17 days	Sat 7/10/06	Tue 24/10/06
5	First core	0 days	Tue 24/10/06	Tue 24/10/06
6	Soft sediment coring	21 days	Tue 24/10/06	Tue 14/11/06
7	Casing	3 days	Tue 14/11/06	Fri 17/11/06
8	HQ coring	13 days	Fri 17/11/06	Thu 30/11/06
9	Downhole logging (incl new mud)	3 days	Thu 30/11/06	Sun 3/12/06
10	Casing	3 days	Sun 3/12/06	Wed 6/12/06
11	NQ coring	21 days	Wed 6/12/06	Wed 27/12/06
12	Last core	0 days	Wed 27/12/06	Wed 27/12/06
13	Downhole logging (incl new mud)	7 days	Wed 27/12/06	Wed 3/01/07
14	Casing Cutting, Plug & Abandon	5 days	Wed 3/01/07	Mon 8/01/07
15	Sea Riser Recovery	4 days	Mon 8/01/07	Fri 12/01/07
16	Contingency	3 days	Fri 12/01/07	Mon 15/01/07
17	Deadline for end of DS ops	0 days	Mon 15/01/07	Mon 15/01/07
18	Decomm & repositioning	15 days	Mon 15/01/07	Tue 30/01/07
19	Prep for SMS & ship offload	20 days	Tue 30/01/07	Mon 19/02/07



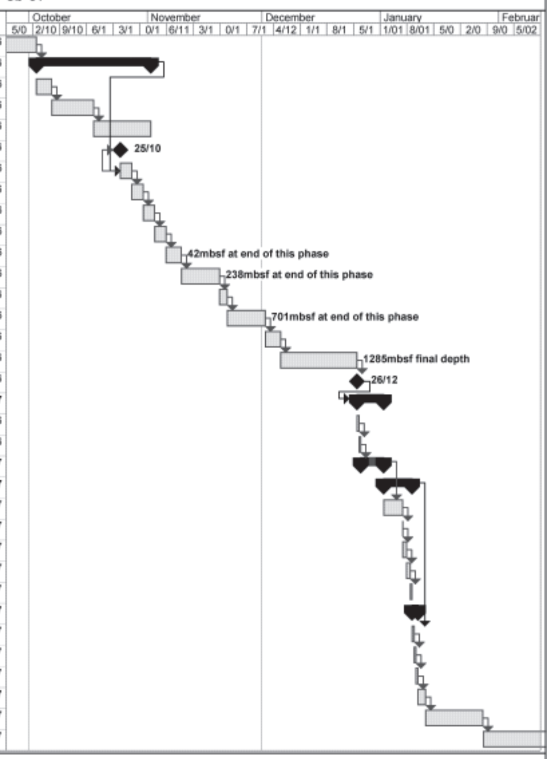
Project: MIS Timeline v1.1 01Aug06.m
Date: Fri 16/02/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Fig. 5 – Pre-drilling schedule and timeline for drilling operations.

MIS Drill Season Timeline v2.0 01 Feb 07

ID	Task Name	Duration	Start	Finish
1	Setup phase 1(Winfly)	46 days	Fri 18/08/06	Tue 3/10/06
2	Setup phase 2	30 days	Tue 3/10/06	Thu 2/11/06
3	SB/Orientation	4 days	Tue 3/10/06	Sat 7/10/06
4	Set up	11 days	Sat 7/10/06	Wed 18/10/06
5	Deploy Sea Riser	15 days	Wed 18/10/06	Thu 2/11/06
6	First core	0 days	Wed 25/10/06	Wed 25/10/06
7	Soft sediment sea floor coring	3 days	Wed 25/10/06	Sat 28/10/06
8	Sea riser embedment & coring (Hole 1A)	3 days	Sat 28/10/06	Tue 31/10/06
9	Sea riser embedment & coring (Hole 1B)	3 days	Tue 31/10/06	Fri 3/11/06
10	Cementing	3 days	Fri 3/11/06	Mon 6/11/06
11	Soft sediment coring below SR shoe	4 days	Mon 6/11/06	Fri 10/11/06
12	PQ coring	10 days	Fri 10/11/06	Mon 20/11/06
13	Casing	2 days	Mon 20/11/06	Wed 22/11/06
14	HQ coring	10 days	Wed 22/11/06	Sat 2/12/06
15	Casing	4 days	Sat 2/12/06	Wed 6/12/06
16	NQ coring	20 days	Wed 6/12/06	Tue 26/12/06
17	Last core	0 days	Tue 26/12/06	Tue 26/12/06
18	**NQ downhole logging**	**6.48 days**	**Tue 26/12/06**	**Mon 1/01/07**
19	Flush & relax hole	6 hrs	Tue 26/12/06	Tue 26/12/06
20	Trip out NQ	9 hrs	Tue 26/12/06	Tue 26/12/06
21	DH logging including clearing bridges, pulling NQ	5.85 days	Tue 26/12/06	Mon 1/01/07
43	**HQ downhole logging**	**7.63 days**	**Mon 1/01/07**	**Tue 9/01/07**
44	HQ casing cutting, trip NQ, trip HQ to base of PQ	5 days	Mon 1/01/07	Sat 6/01/07
45	Initial logging of HQ hole	3 hrs	Sat 6/01/07	Sat 6/01/07
46	Trip out remainder of HQ casing	1 day	Sat 6/01/07	Sun 7/01/07
47	Remainder of HQ logging	1 day	Sun 7/01/07	Mon 8/01/07
48	VSP and walkaway seismic	0.5 days	Mon 8/01/07	Tue 9/01/07
49	**PQ casing cutting and trip out PQ**	**1.5 days**	**Tue 9/01/07**	**Wed 10/01/07**
50	Run in HQ casing (w PQ casing cutter)	12 hrs	Tue 9/01/07	Tue 9/01/07
51	Trip out HQ casing to sledge in 6m lengths	12 hrs	Tue 9/01/07	Wed 10/01/07
52	Trip out PQ casing	12 hrs	Wed 10/01/07	Wed 10/01/07
53	**Sea Riser Recovery**	**2 days**	**Wed 10/01/07**	**Fri 12/01/07**
54	Decomm & repositioning	15 days	Fri 12/01/07	Sat 27/01/07
55	Prep for SMS & ship offload	24 days	Sat 27/01/07	Tue 20/02/07



Project: MIS Timeline v2.0 01Feb07
Date: Fri 16/02/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Fig. 6 – Actual schedule and timeline for drilling operations.

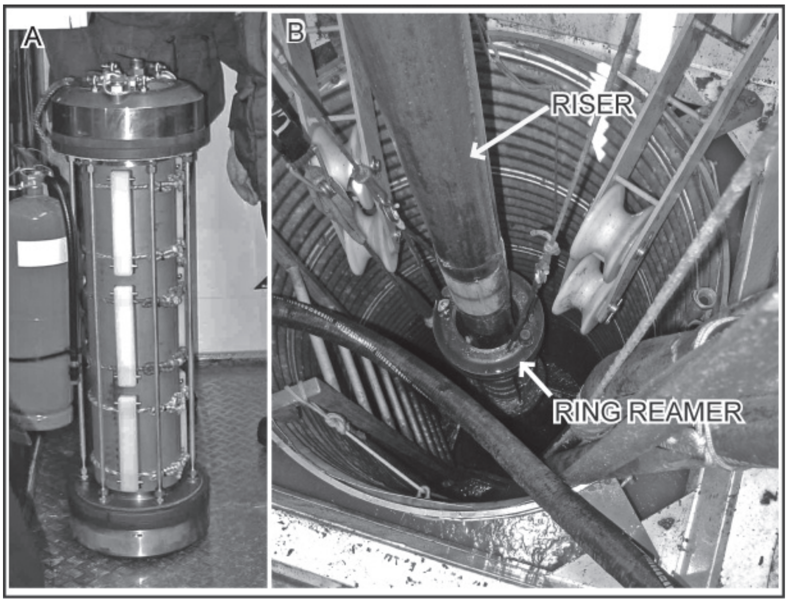


Fig. 7 – Hot water reamer tool (A) and (B) view from the drill rig cellar looking down the ice shelf hole and at the ring reamer in operational position around the riser.

HOT WATER DRILL (HWD)

The HWD system is designed to keep the sea riser free of the ice shelf, which floats and moves with the tide. The over reamer tool, used to ream the ice shelf hole once the sea riser is in place, runs down a wire guide on the sea riser. Heated seawater (at approximately 85°-90°C) jets out of the reamer from the bottom ring when the tool is lowered down the ice-shelf hole, or out the top ring when it is lifted back through the hole (Fig. 7). When not in use, the reamer is parked about 2 m below the cellar floor in the cellar well.

Hot water reaming of the hole was carried out at scheduled times throughout drilling operations. These times were separated by incrementally longer periods as the drill season progressed because refreezing in the relatively 'short' ice shelf hole was not as rapid as initially expected (Tab. 1). Running the HWD system up and down the ice shelf hole identified ice obstructions in the path of the reamer and allowed the drilling operations team to develop a better understanding of ice regrowth. Clear runs with the reamer indicated that there had been little regrowth over the intervening period, which suggested that time intervals between reams could be extended. This effective reduction in scheduled HWD reaming activity resulted in significant time and fuel savings.

Tab. 1 - Hot-water drill reaming of the ice-shelf hole.

Date	***Details***
2-3 October 2006	Set up to run HWD
5 October 2006	Melted out well in cellar
12-13 October 2006	Drilled to base of ice shelf with pilot lance
14 October 2006	Installed submersible pump and reamed hole to base of ice shelf with back reamer
15 October 2006	Reamed hole to base of ice shelf with over- reamer
21 October 2006	Reamed hole with ring reamer over sea riser
24 October 2006	Hot water mud in sea riser
4 November 2006	Reamed hole with ring reamer
12 November 2006	Reamed hole with ring reamer
23 November 2006	Reamed hole with ring reamer (did not exit hole)
8 December 2006	Reamed hole with ring reamer (did not exit hole)
10 January 2007	Reamed hole with ring reamer

On 12 November 2006, during a scheduled reaming operation, it became difficult to break through the bottom of the ice shelf and bring the reamer tool back into the hole. Drilling management team members determined that the tool was probably jamming because the riser had moved from its original position in the centre of the ice shelf hole and was now lying against the side of the hole. This offset of the riser was likely due to combined lateral movement of the ice shelf and strong water currents. It also became clear that complete reaming of the hole resulted in periods of increased sea riser movement (vibration) over the 1–2 days following reaming operations. This increase in vibration provided challenges to drilling, at times causing a complete halt in coring progress. Because of the vibration problem, no attempt was made to exit the base of the ice shelf with the hot water reamer after 23 November 2006.

SEA RISER EMBEDMENT AND SEDIMENT CORING

SEA RISER EMBEDMENT

The sea riser was embedded into the seafloor on 2 November 2006 on the second spud-in attempt at 17.18 m below seafloor (mbsf) where the riser shoe and casing were cemented back to approximately 4.26 mbsf. The riser embedment process used a rotating sea riser shoe driven by a splined section on the PQ coring barrel on the PHD drill string that was rotated within the sea riser casing (Fig. 8). This approach enabled coring to continue during riser spud-in and did not require the riser casing to rotate. Soft-sediment coring barrel assemblies were used during the spud-in process, but core recovery was mediocre.

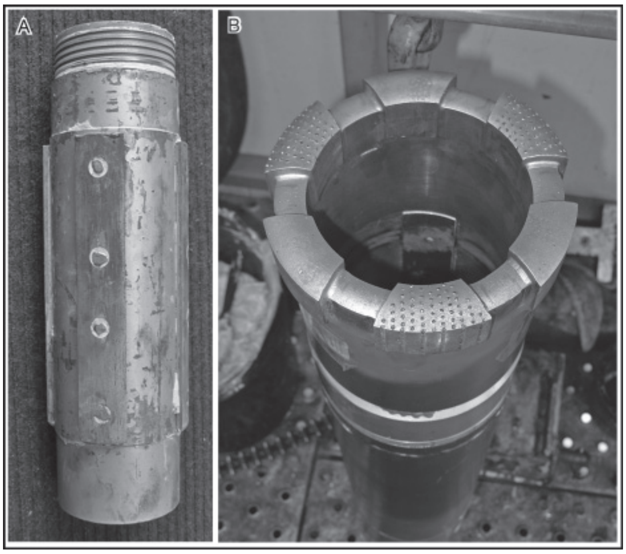


Fig. 8 – Images of the splined section on the PQ coring barrel (A) and riser shoe (B).

Low-temperature permafrost cement was used to grout in the riser. Once set, over-tension was applied to the riser. This increased tension was added to that created by the weight of the riser in the water column. When the PHD and HQ/HRQ casing were cemented in the seafloor additional tension was applied to the riser to hold the added weight of the casings.

SOFT-SEDIMENT CORING

Soft-sediment coring commenced on 25 October 2006 with a series of four push cores. Coring continued on 26 October 2006 with an attempt to recover sediments using an extended nose coring system, which was deployed ahead of the sea riser. Following the extended nose coring attempt, the P drill string was tripped out of the hole, as it was determined that the core barrel had been bent during the coring process.

Drillhole ANDRILL (AND)-1A was started on 28 October 2006 and, using standard alien, push corer and extended- nose soft-sediment coring assemblies, cored down to 10.23 mbsf by 30 October 2006. At this point in the coring operation it became impossible to retrieve the soft-sediment tool inner tubes, as they would not pass a bend in the sea riser approximately 30 m above the seafloor. The ANDRILL management team decided to pull the drill string and riser and commence a new drillhole.

Drillhole AND-1B was started on 31 October 2006. Coring continued using the alien and extended alien coring assemblies as far as 17.09 mbsf at which point drilling operations management decided to cement the sea riser in place. This decision was based on suspected wear on the sea riser shoe. On 6 November 2006 soft-sediment coring recommenced using the extended alien coring assembly and continued to a depth of 41.88 mbsf, which was reached on 9 November using both extended alien and standard alien drill bits.

PQ CORING

PQ3WL coring commenced on 10 November 2006 and continued to 20 November 2006 reaching a depth of 238.04 mbsf. The decision to stop PQ coring was based on analysis of sonic velocity data that indicated the bit had reached a zone of hard lithologies that were suitable for cementing in the casing. The PQ bit and barrel assembly were cemented in place with Permafrost C grout. A casing shoe was not used due to the high risk that the borehole would collapse if the PHD drill string were tripped out of the hole.

High drilling fluid losses during PQ coring and resulting high consumption of drilling fluids products during PQ coring meant that additional supplies of KCl had to be ordered from New Zealand and flown to Antarctica.

HQ CORING

HQ coring commenced on 22 November 2006 at a depth of 237.77 mbsf and was terminated on 2 December 2006 when the HQ string became stuck in the hole with the bit at 700.65 mbsf. The drill crew managed to pull the bit back approximately 9 m from bottom of the hole before the string became completely stuck. Drilling fluid return was initially lost on 30 November, likely due to fluid loss to the formation within a fracture zone in the upper part of a thin lava flow at approx 647 mbsf. Drilling fluid loss continued even after the drill string became stuck. Furthermore, the wireline was damaged during attempts to trip the inner tube. Drilling operations management decided to wait for a replacement wireline to arrive from New Zealand and be installed on the rig before proceeding to remove the inner tube and continue attempts to dislodge the HQ string. Once the new wireline was installed the inner tube with the final HQ core was successfully recovered. At this time it was decided to case off the HQ string, as 1) the string remained stuck and 2) the rig was close to its handling capacity for HQ coring. The decision to case at this level meant that an HQ size cavity continued for 9 m beneath the HQ bit.

The HQ barrel and bit were cemented using the Permafrost C grout. Because the drill bit was not placed at the bottom of the hole the grout became cut with drilling fluid and did not set properly. However, the seal that formed around the HQ casing was sufficient to allow drilling fluid return while coring the upper part of the NQ hole.

NQ CORING

NQ coring commenced on 6 December 2006 at a depth of 701.62 mbsf. Fluid return was completely lost on 12 December 2006 at about 831 mbsf but coring continued successfully through to a final depth of 1284.87 mbsf reached on 26 December 2006.

DOWNHOLE LOGGING

Downhole logging was carried out in the borehole casing and in parts of the open hole. Although the quality of core recovered from the AND-1B hole was excellent, the gauge of the borehole for much of the cored interval was variable. The hole was often over gauge, especially in zones that were logged above 924 mbsf.

Following logging runs inside the NQ drill string, open hole (NQ) from below the HQ drill bit (690 mbsf) to approximately 1000 mbsf was made available for logging.

Four cutting attempts at increasingly shallower depths were made on the HQ casing before it came free as the HQ casing was stuck higher on the drill string than was initially expected. The interval of open HQ hole below the PQ drill bit, from 238 to 340 mbsf, was available for logging, as was a 55 m interval lower in the hole, which was partially logged from 528 to 583 mbsf. This lower open interval developed when the HQ casing dropped into the over gauge NQ hole following one of the early cutting attempts.

None of the open PQ hole was made available for logging.

CASING AND SEA RISER CUTTING AND RECOVERY

Mechanical cutters attached to the NRQ and HQ/HRQ drill strings were used to cut the HQ/HRQ and PHD casings. The HQ/HRQ casing was cut at 640.5, 587.5, 540.0 and 344.5 mbsf.

The PHD casing was cut at 210 and 162 mbsf. The sea riser was cut off just above the seafloor with an explosive colliding detonation cutter deployed by the wireline and fired electrically. The first attempt to cut the riser was unsuccessful due to a water leak around the detonator connection. The second attempt detonated successfully but required a subsequent 22 tonnes of overpull to release the riser pipe at the cut.

CORE MANAGEMENT AND SCIENCE OPERATIONS

Core management and scientific activities occurred at the MIS Project drill site and at McMurdo Station.

PROTOCOL FOR HOLE, CORE, AND BOX NOMENCLATURE

A core and sampling identification protocol was developed and circulated to members of the McMurdo Sound ANDRILL Science Implementation Committee (M-ASIC) for comment and approval. The core naming protocol for the primary ANDRILL hole(s) is outlined in table 2. Depths are always given to the nearest centimetre.

DRILL SITE

During the main drilling phase of the project, core was recovered in 3 and 6 m runs and was delivered from the drill rig to the drill-site laboratory complex, which comprised six converted shipping containers. In the laboratory complex a two-person processing team cleaned and scribed the core with a red and blue line (at 180° from each other) and logged core recovery. In addition, members of the core structure measurements group (CSMG) made initial measurements on natural and drilling-induced fractures. The core was then cut into 1 m lengths by the core technicians and placed into one half of a split PVC pipe to enhance core handling and maintain core integrity. The 1 m lengths were then transferred to a DMT core scanner and whole-round images were obtained. Core was then run through a Geotek multisensor core logger to obtain a suite of physical-properties measurements. Once the physical-properties measurements were completed, the core was sandwiched between two PVC splits, sealed into lay-flat plastic liner, and placed in aluminium core transport boxes.

TRANSPORT TO MCMURDO STATION

Curatorial staff collected core from the drill site at approximately 1000 and 2200 h each day. USAP Ford F-350 pickup trucks equipped with Mattracks were used to transport empty core transport boxes to the drill site and return core to McMurdo Station. On average, seven aluminium core transport boxes packed with core were collected on each trip. Core-catcher material and all associated paperwork were also transported at the same time.

Tab. 2 - MIS drill core identification and nomenclature.

Organisation	ANDRILL
Project[1]	001
Site[2]	001
Hole	A
Run number	001
Interval within core barrel[3] (m)	0.30– 0.40
Core type[4]	H, X, or R
Interval[5] (from splice) (mbsf)	0–0.5 m
Core transport box number[6]	001
Split core box number[7]	001 (A or W)

[1]Replaces McMurdo Ice Shelf (MIS) Project.
[2]A site is defined by an individual hole in the ice.
[3]If multiple hydraulic piston cores (H) are obtained, they will be spliced together and a conversion from metres composite depth (MCD) to metres below seafloor (mbsf) determined as soon as possible.
[4]H = hydraulic piston cores, X = extended core barrel, R = rotary core.
[5]Only required for initial splicing of HPCs.
[6]From Core Recovery Log.
[7]Curatorial use only: A = archive half, W = working half.

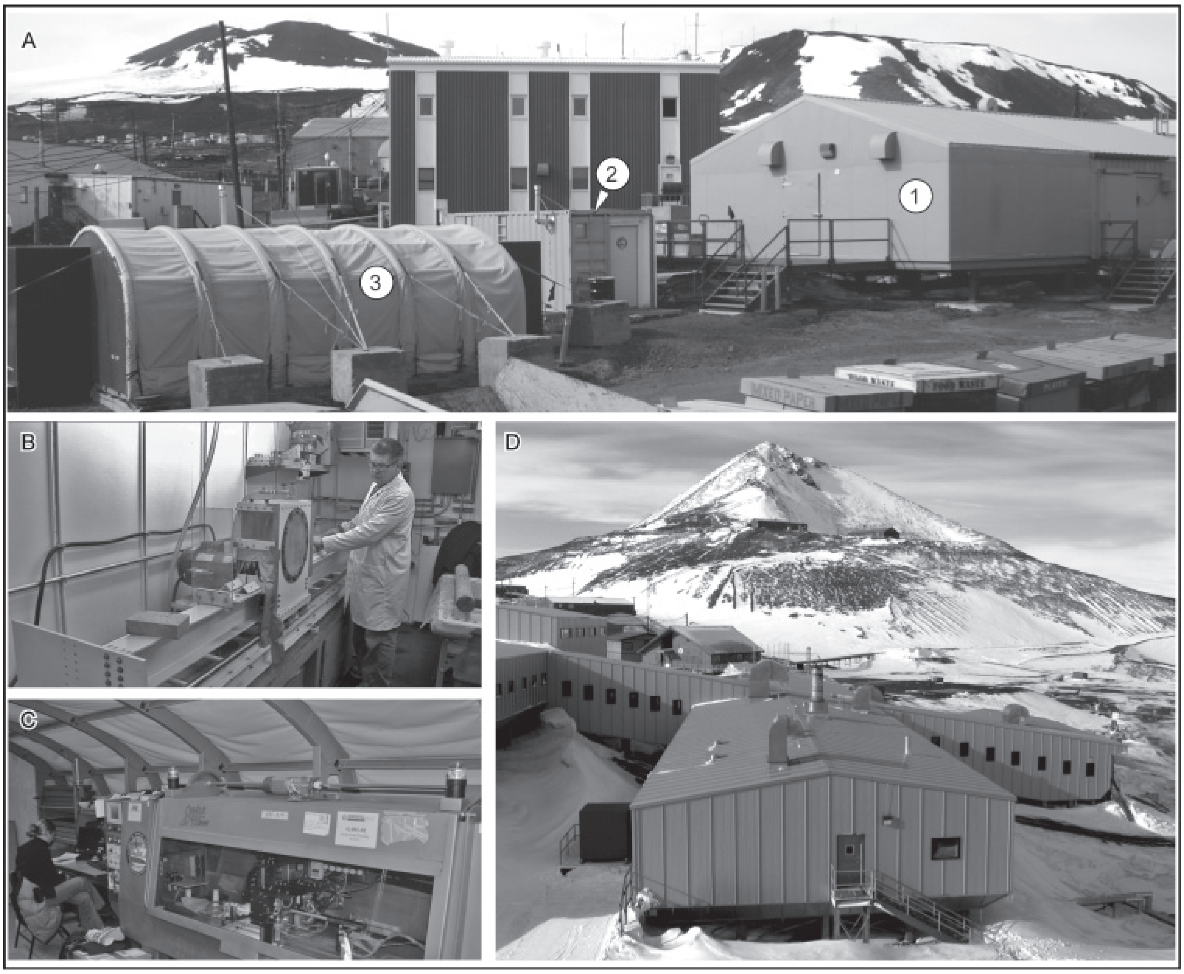


Fig. 9 – Work centres at McMurdo Station: (A) Image showing the Core Storage Facility (1) the Mobile Lab Van [MLV] (2), and Rac Tent (3). (B) Image of the core splitter saw inside the MLV. (C) Image of the Avaatech XRF scanner inside the Rac Tent. (D) The Crary Science and Engineering Centre (CSEC).

MCMURDO STATION

Core management and scientific activities occurred at four primary locations at McMurdo Station: (1) Core Storage Facility (CSF); (2) Florida State University's Antarctic Marine Geology Research Facility Mobile Laboratory Van (MLV); (3) RAC-Tent Scanning Facility (RTSF); and (4) Crary Science and Engineering Center (CSEC) (Fig. 9).

When core arrived from the drill site the transport boxes were stacked inside the MLV or in the CSF if there was a backlog of core in the MLV. At times core recovery at the drill site was so rapid that core had to be unloaded from the aluminium boxes and stacked on vacant shelves in the CSF so that empty core transport boxes could be sent back to the drill site to keep up with increased core flow.

ANTARCTIC MARINE GEOLOGY RESEARCH FACILITY (AMGRF) MOBILE LABORATORY VAN: CORE SPLITTING

The following describes the core splitting procedure for both soft and lithified core:

i. If the core was contained in soft-sediment liner it was cut longitudinally using a double razor-blade apparatus built into the core splitter. The core was then cut into archive and working halves using a wire pulled through the core by hand.
ii. Lithified core was stored between two PVC splits, one of which had been labelled at the drill site. The unlabeled PVC split liner for each section of lithified core was labelled in the MLV. One split was then removed and the core was checked to ensure that it was aligned correctly with the blue and red scribe lines oriented 90° from the edge of the split.
iii. Each 1 m section of lithified whole core was cut longitudinally into an archive half and a working half using a rotary diamond saw. The cores were split along the plane at 90° to the scribe lines; the half with the red scribe became the archive half and the half with the blue scribe became the working half. The saw blade was changed approximately every 300 m. Note that splitting PQ core caused significantly faster wear on the blades than either HQ or NQ core.
iv. Each split-core section was allocated a blue (for working half) or white (for archive half) plastic label with the following information: core identification; interval (in metres), 'top', and 'archive' or 'working'. Each label was placed at the top of the relevant split core. Note that a blue label was used for the

working half as this was imaged and the line scan camera generally does not over expose blue.

v. Archive and working halves (for both soft and lithified core) were covered in plastic wrap and placed into wax-cardboard core boxes (2 m per box for PQ core, 3 m per box for HQ core, and 4 m per box for NQ core). Approximately 850 wax-cardboard boxes were used during the project.

vi. Plastic dividers with depth in metres below seafloor (mbsf) written on them were placed in the core boxes at the top and bottom of each 1 m interval. All voids within the core section were filled with foam.

vii. The end of the cardboard core box was scraped clean of wax and labelled with the appropriate core information including box number, run number, metres below seafloor (mbsf) top and bottom, and either 'archive' or 'working' as relevant.

viii. At the end of each shift the saw was cleaned and, when necessary, lubricated.

RAC-TENT SCANNING FACILITY (RTSF): CORE IMAGING AND XRF SCANNING

i. Archive and working halves of the core were carried in the cardboard core boxes from the MLV to the adjacent RTSF [fig. 9].

ii. The archive half was scanned with an AVAATECH XRF scanner (to obtain XRF data and a line-scan image) and a Minolta spectrophotometer.

iii. When XRF scanning was complete the archive split was wrapped and sealed, returned to the appropriate wax-cardboard storage box, and carried back to the CSF.

iv. The working half of each core section was imaged at a resolution of 500 dots/cm using a Nikon line scan camera with a AF Nikkor 50 mm 1:1.8D lens. The camera was mounted on a GEOTEK multisensor core scanner track. Each 1 m section took approximately 18 min to scan. A total of 1 254 core sections were scanned.

v. When the imaging process was finished, the working half was wrapped and sealed, returned to the appropriate wax-cardboard storage box, carried to the CSF, and stacked on shelves clearly separated from the archive halves.

vi. At the start of the CSEC night shift (2200), between nine and twelve wax-cardboard boxes were packed into vinyl insulated carrying bags and transferred to CSEC Room 201 by hand-carry or via pickup truck. Core was then laid out for visual core description.

CSEC ROOM 201: VISUAL CORE DESCRIPTION (VCD) AND DESTRUCTIVE SAMPLING

A core description and sampling laboratory was set up in Room 201 in the CSEC. The room was arranged to accommodate approximately 10 m of bench space arranged in four rows (one long bench against the north wall, one long bench extending from the sink to the door, one from the loading dock door edge towards the door and a shorter one along the south wall). High-intensity halogen lighting was used to augment the fluorescent lighting to enhance core-viewing capability. The temperature of Room 201 was maintained at ~18°C and one humidifier was used to enhance the humidity level achieved with CSEC's built in facilities. The floor, benches, and all equipment in the room were thoroughly cleaned at the end of each viewing/sampling session to minimise the potential for contamination of the next batch of core.

VISUAL CORE DESCRIPTION

Members of the sedimentology team logged the core during the night shift (2200–1000) and created a graphic core log using PSICAT (Palaeontological Stratigraphic Interval Construction and Analysis Tool) VCD software. When sections of core had been described, they were rewrapped in plastic film and placed in the appropriate wax-cardboard boxes. An average of 26 m of core was logged per night shift (minimum 7 m, maximum 60 m). At the end of each night shift, upon completion of VCD activities, the core was laid out on the benches in stratigraphic sequence in preparation for the core tour and sampling.

CORE SAMPLING

High-priority sampling

Curatorial staff took half-round and full-round samples for interstitial water (IW) studies as soon as the core was split or unpacked. IW samples were wrapped in cling-film and placed in a labelled sample bag in the refrigerator in CSEC Room 219 or given directly to pore-water geochemistry personnel.

One high-priority whole-round sample was taken for structural analysis.

Standard sampling

Core tours were conducted each morning immediately following the science team meeting held in the CSEC seminar room. Sections of core were laid out on benches in CSEC 201; science team members examined the core and selected samples by placing disposable sample flags (a toothpick with an adhesive label wrapped around it) at relevant positions alongside the core. A total of 5308 samples were taken on-ice, of which 920 (~18%) were made into thin sections.

Disputed sample intervals

Overlapping sample requests were resolved through discussions with the science team member(s) involved, the curators, and the ANDRILL sample committee. The sample committee comprised the co-chief scientists, staff scientist, head curator, and discipline team leaders (DTLs).

Sampling procedure

Common laboratory spatulas, small scoops, plastic tubes, etc., were used to remove samples from unlithified core. Two table saws with diamond rock-cutting blades were used to cut lithified matrix and clasts. All sampling tools were cleaned prior to use. Voids left in the core following extraction of samples were filled with foam blocks to help stabilise the core.

Palaeomagnetic sampling procedure

Members of the palaeomagnetics team conducted their own sampling. To avoid contamination of the core, orientated, coherent sections were removed from the core box, placed on a carrying tray, and taken to the palaeomagnetic sampling lab (located on the loading dock of CSEC Room 201). A hollow, thin-kerf diamond drill was used to remove the sample and the remaining core section was replaced in the core box in the proper orientation.

Sample data entry

The curators entered all sample interval data into a database. These data included investigator's name, core number, box number, run number, sample interval (mbsf), sample volume (cubic centimetre), date, and comments. The comments section included type of sample (*e.g.* sediment, fossil, or clast) and the discipline and type of analysis to be performed on each sample (*e.g.* petrology thin section or palaeontology diatoms). Sample and coring information is accessible through the web site of the AMGRF at the Florida State University(FSU) http://www.arf.fsu.edu.

Core Storage

When sampling was completed, each 1 m section of core was misted with deionised water and wrapped in plastic film (to help retard desiccation) and placed in the appropriate wax-cardboard box. The boxes were then loaded into vinyl carrying cases for transport via pickup truck to the CSF.

CORE STORAGE AND TRANSPORT

Storage

Once core had been processed it was placed on shelves in the CSF. Temperature in the CSF was maintained between 2° and 5°C (35° and 41°F). Humidity levels were augmented with two humidifiers to maintain the highest possible level of humidity (approximately 76%).

Preparation for Core Shipment to Florida State University

Wax-cardboard core boxes were placed into specially constructed wooden crates that contain nine separate compartments holding four boxes each. Crates were marked with arrows pointing to the upright position and with signs designating the correct temperature for transport (4°C/40°F). Crates were placed, using a forklift, into two refrigerated ISO shipping containers. The shipping containers were later transferred to the cargo ship *Greenwave* for shipment to the AMGRF at FSU via Lyttleton, New Zealand, and Port Hueneme, California, where they were transferred to truck for overland transport to Tallahassee, Florida.

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